

MAY 11 1969

Fm



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MSC INTERNAL NOTE NO. 69-FM-129

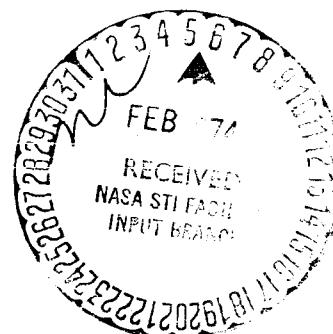
May 12, 1969

FEB 9 1970

Technical Library, Bellcomm, Inc.

INTERNAL NOTE No. 69-FM-129

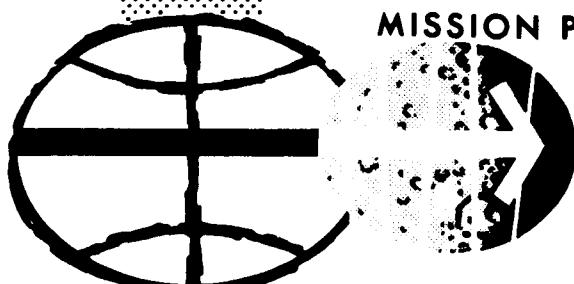
# VERIFICATION OF THE RTCC POWERED FLIGHT SIMULATION FOR APOLLO 10 (MISSION F)



Guidance and Performance Branch

MISSION PLANNING AND ANALYSIS DIVISION

MANNED SPACECRAFT CENTER  
HOUSTON, TEXAS



(NASA-TM-X-69672) VERIFICATION OF THE  
RTCC POWERED FLIGHT SIMULATION APOLLO 10  
(MISSION F) FOR (NASA) 36 p

N74-70640

00/99 Unclassified  
16214

MSC INTERNAL NOTE NO. 69-FM-129

---

PROJECT APOLLO

VERIFICATION OF THE RTCC POWERED FLIGHT  
SIMULATION FOR APOLLO 10 (MISSION F)

By Harry J. Miles  
Guidance and Performance Branch

---

May 12, 1969

MISSION PLANNING AND ANALYSIS DIVISION  
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
MANNED SPACECRAFT CENTER  
HOUSTON, TEXAS

Approved:

  
Marlowe D. Cassetti, Chief

Guidance and Performance Branch

Approved:

  
John P. Mayer, Chief

Mission Planning and Analysis Division

## CONTENTS

Section	Page
SUMMARY . . . . .	1
INTRODUCTION . . . . .	1
SYMBOLS . . . . .	2
DISCUSSION . . . . .	3
CSM SPS Maneuvers . . . . .	3
LM DPS and APS Maneuvers . . . . .	4
AGS Targeting . . . . .	5
RCS Translation Maneuver . . . . .	6
CONCLUSION . . . . .	6

## TABLES

Table		Page
I	CASE 1: TRANSLUNAR MIDCOURSE CORRECTION, EARTH REFERENCE . . . . .	7
II	CASE 2: LOI-1, MOON REFERENCE . . . . .	8
III	CASE 3: LOI-2, MOON REFERENCE . . . . .	9
IV	CASE 4: TRANSLUNAR MIDCOURSE CORRECTION, EARTH REFERENCE . . . . .	10
V	CASE 5: LOI-1, MOON REFERENCE . . . . .	11
VI	CASE 6: PLANE CHANGE, MOON REFERENCE . . . . .	12
VII	CASE 7: PLANE CHANGE, EARTH REFERENCE . . . . .	13
VIII	CASE 8: MINIMUM IMPULSE, EARTH REFERENCE . . . . .	14
IX	CASE 9: TRANSLUNAR MIDCOURSE CORRECTION, EARTH REFERENCE . . . . .	15
X	ANGULAR DIFFERENCE BETWEEN XIMU'S . . . . .	16
XI	CASE 10: DPS MINIMUM IMPULSE, MOON REFERENCE . . . . .	17
XII	CASE 11: DPS HEIGHT ADJUSTMENT, MOON REFERENCE . . . . .	18
XIII	CASE 12: APS MINIMUM IMPULSE, MOON REFERENCE . . . . .	19
XIV	CASE 13: APS PLANE CHANGE, MOON REFERENCE . . . . .	20
XV	CASE 14: APS APOLUNE CHANGE, MOON REFERENCE . . . . .	21
XVI	CASE 15: APS APOGEE CHANGE, EARTH REFERENCE . . . . .	22
XVII	CASE 16: DPS PLANE CHANGE, EARTH REFERENCE . . . . .	23
XVIII	CASE 17: LM RCS EXTERNAL ΔV BURN . . . . .	24
XIX	CASE 18: LONG APS BURN 6D . . . . .	25
XX	CASE 18a: LONG APS BURN 3D . . . . .	26

Table		Page
XXI	COMPARISON OF COMPUTED LM REFSMMAT . . . . .	27
XXII	CASE 19: DPS EXTERNAL ΔV BURN 6D AND 3D . . . . .	28
XXIII	CASE 20: APS EXTERNAL ΔV BURN, 6D AND 3D . . . . .	29
XXIV	CASE 21: APS EXTERNAL ΔV BURN, 6D AND 3D . . . . .	30

VERIFICATION OF THE RTCC POWERED FLIGHT SIMULATION

FOR APOLLO 10 (MISSION F)

By Harry J. Miles

SUMMARY

The results of the Guidance and Performance Branch (GPB) verification of the Real-Time Computer Complex (RTCC) powered flight simulation for the Apollo 10 mission are presented. The testing is completed; and, based on the results presented, the GPB feels that the RTCC simulation of powered flight adequately reflects expected spacecraft performance.

INTRODUCTION

In this report, the results of 18 cases are presented which approximate Apollo 10 (Mission F) powered flight maneuvers. The cases presented are as follows: nine command/service module (CSM) service propulsion system (SPS) maneuvers, three lunar module (LM) descent propulsion system (DPS) maneuvers, five LM ascent propulsion system (APS) maneuvers, and one LM reaction control system (RCS) maneuver. All cases were simulated with six degrees of freedom (6D) by use of the primary guidance and navigation control system (PGNCS). Additionally, one LM DPS and two LM APS maneuvers were simulated with both six degrees of freedom and three degrees of freedom (3D) by use of the abort guidance system (AGS). The intent of the data presented in this report is to verify that the RTCC is capable of mission support for Apollo 10 (Mission F). The results are presented in tables I through XXIV. All symbols used in these tables are defined in the list of symbols. Data for the verification presented in this document were obtained primarily from references 1, 2, 3, and 4.

SYMBOLS<sup>a</sup>

$\Delta T_B$  main engine burn duration in seconds

$\Delta V_x$   
 $\Delta V_y$   
 $\Delta V_z$

} components of rotated  $\Delta V$  targets, fps

$\Delta V_m$  magnitude of rotated  $\Delta V$  targets, fps

$V_{gx}$   
 $V_{gy}$   
 $V_{gz}$

}  $V_g$  residuals, fps

XIMUX  
XIMUY  
XIMUZ

} direction cosines of XIMU referenced to ECI

YIMUX  
YIMUY  
YIMUZ

} direction cosines of YIMU referenced to ECI

ZIMUX  
ZIMUY  
ZIMUZ

} direction cosines of ZIMU referenced to ECI

*a* resultant semimajor axis, n. mi.

*e* resultant eccentricity

*i* resultant inclination, deg

$\omega_g$  resultant argument of perigee

$\Omega$  longitude of ascending node after maneuver

---

<sup>a</sup>This list of symbols compares the RTCC Detailed Maneuver Table. display parameters that result from the external  $\Delta V$  powered flight simulations of the RTCC and MPAD's Guidance and Performance Branch (GPB).

f true anomaly after maneuver

NA not applicable

PRTIM }  
YTRIM } trim angles to get the thrust through the c.g.

IGA }  
MGA } IMU gimbal angles at main engine ignition  
OGA }

YAW }  
PITCH } spacecraft body attitudes at main engine ignition relative  
ROLL } to the local horizontal system, deg

## DISCUSSION

### CSM SPS Maneuvers

Nine CSM SPS maneuvers simulated for comparison by the RTCC and GPB are described in cases 1 through 9. Cases 1, 2, 3, 4, and 5 are CSM SPS docked G&N maneuvers; cases 6, 7, 8, and 9 are undocked maneuvers. The parameters used for comparison are those displayed during real time on the Detailed Maneuver Table (DMT) to describe spacecraft maneuvers. The results indicate good agreement between GPB's engineering simulation (ARMP, 6D program) and that of the RTCC.

A specified and preferred inertial measurement unit (IMU) alignment was simulated for each SPS maneuver, and the REFSMMAT's (matrix required to transform a vector from the basic reference coordinate system to the stable member coordinate system) that result from the preferred alignment are presented for comparison in tables I through X. The preferred REFSMMAT computation is a function of the spacecraft center-of-gravity (c.g.) location. The X stable member of the IMU is rotated from the desired thrust direction by the pitch and yaw angles that describe the vehicle's c.g. location with respect to the X-body axis. The preferred IMU orientation allows the spacecraft gimbal angles to read  $0^\circ$ ,  $0^\circ$ ,  $0^\circ$ , when the spacecraft maneuvers to the preferred attitude. In the GPB simulation of the nine SPS maneuvers, there was an initial desired thrust

direction difference when compared to the RTCC results. The thrust direction difference was caused by a roundoff of the external  $\Delta V$  targets supplied by the RTCC for each maneuver. The difference in desired thrust direction is shown in table X. The angular difference between the GPB and RTCC X stable members are shown in table X. Also shown are the angular differences between the c.g. locations for each case simulated. When the angular difference between the XIMU's noted in cases 6 through 9 of table X is analyzed, two conclusions may be drawn: (1) the c.g. data used by the GPB and the RTCC for the undocked vehicle do not show as good agreement as those used for the docked vehicle, and (2) the shorter the burn, the larger the angular difference will be in the undocked configuration. The data indicate that the IMU orientation comparison would be within  $0.02^\circ$  if equivalent vehicle mass properties and the same targets had been simulated by the GPB and the RTCC. Likewise, PTRIM, YTRIM (SPS engine trim angles), and IMU gimbal angles would show a much better agreement.

All nine SPS maneuvers were performed with an ullage maneuver. The gimbal angles shown for all SPS maneuvers resulted from alinement to an input REFSMMAT. There is a slight difference between the RTCC and the GPB results because the GPB used a 6D ullage and the RTCC used a 3D ullage.

The same step thrust and flow rate model was used by the GPB and the RTCC in their CSM SPS maneuver simulations. The RTCC will update the values used in their engine models as new data become available for Apollo 10 (Mission F). The GPB reviewed the latest RTCC constants which describe the SPS engine model. The GPB has recommended to the RTCC to update MC7STI' (impulse caused by tailoff) to the value of 13 690 lb-sec. Because the RTCC used old impulse data during tailoff, there were large residuals in most of the SPS maneuvers. The RTCC continues to burn until zero residuals are obtained, whereas the GPB simulates the actual tailoff model. These impulse data in the RTCC have been updated.

#### LM DPS and APS Maneuvers

The results of the LM DPS maneuvers are described in cases 10, 11, and 16; and the LM APS maneuvers simulated by the GPB for verification of the RTCC are described in cases 12, 13, 14, and 18. All cases are undocked maneuvers. The IMU alinement was preferred for all cases. Additionally, case 10 was also performed by alinement to a unity REFSMMAT. (Note that REFSMMAT shown for case 10 results from the preferred alinement case, while the gimbal angles shown in the same case resulted from the unity REFSMMAT). To compare results easily,

the GPB incorporated the RTCC engine model into their simulation. To compute a preferred LM REFSMMAT, a desired thrust direction is computed based on the local vertical targets, the onboard thrust, the state vector at ignition, and the ignition time. Because the targets used by the GPB in their simulation were the rounded-off RTCC targets, there was a slight difference in the desired thrust direction computation. Therefore, the preferred IMU orientation will also be slightly different, which will cause a difference in REFSMMAT for all LM DPS and APS maneuvers. The PTRIM and YTRIM (DPS trim angles) would show almost exact agreement if equivalent vehicle mass properties and desired thrust direction had been simulated by the GPB and the RTCC. Because the APS engine is not gimballed, the trim angle values are fixed, and the effects of thrust mistrim (thrust not through the c.g.) can have a noticeable effect on the maneuver duration and maneuver accuracy. The LM RCS jets are used for spacecraft attitude control; and, depending on vehicle c.g. location, the RCS thrust could aid or hinder the time required to achieve the desired ΔV. Case 18 presents a good example of the effects that thrust mistrim can have on a large APS maneuver. The GPB simulated case 18 with both 3D and 6D to show the difference.

All LM maneuvers were done with 6D ullage. The ullage maneuver time for all DPS maneuvers was 15 seconds, and the ullage maneuver time for all APS maneuvers was 4 seconds. The GPB will show small gimbal angles at burn initiation for all LM maneuvers. The RTCC data show 0° gimbal angles at maneuver initiation, because a 3D ullage was used.

The only discrepancy detected in simulation of the LM DPS and APS maneuvers was that the RTCC used the old impulse data during tailoff for the DPS maneuvers. Use of the old impulse data caused the large residuals in all DPS maneuvers. These data have been updated by the RTCC. The GPB feels that the RTCC simulation of the LM DPS and APS powered flight is adequate to support Apollo 10 (Mission F). The DPS and APS engine model constants have been reviewed and were found to be the latest.

#### AGS Targeting

For LM PGNCS maneuvers, the RTCC displays the required AGS targets that result in the equivalent trajectory achieved by the LM primary guidance targets. Cases 19, 20, and 21 were simulated by the GPB with both 6D and 3D by use of the displayed AGS targets. The results of these simulations are shown in tables XXII through XXIV.

## RCS Translation Maneuver

Case 17 is a LM RCS maneuver which is a PGNCS controlled burn. A preferred REFSMMAT was calculated and compared for this maneuver. The preferred REFSMMAT orientation for this RCS maneuver alines the XIMU along the desired thrusting direction. The RCS results shown in table XVIII are very good.

As indicated in reference 5, the GPB did verify the RTCC's computation of the LM docked REFSMMAT. The results of the independent computations made by the GPB and by the RTCC are shown in table XXI. The comparisons are very good. Given the CSM/LM docking angle, the LM gimbal angles, the CSM gimbal angles, and the CSM REFSMMAT, the RTCC computes the LM REFSMMAT.

## CONCLUSION

As demonstrated by the data, no major differences exist between the powered flight simulations that are compared, and all simulations are capable of mission support. The GPB will continue to support the RTCC in the areas of powered flight simulation for the Apollo 10 Mission.

TABLE I.- CASE 1: TRANSLUNAR MIDCOURSE CORRECTION, EARTH REFERENCE

Parameter	GPB value	RTCC value	RTCC - GPB difference
$\Delta t$ burn	3.263	3.270	0.007
$\Delta V_x$	3.200	3.200	0.0
$\Delta V_y$	-0.100	-0.100	0.0
$\Delta V_z$	23.300	23.300	0.0
$\Delta V_m$	23.500	23.500	0.0
$v_{gx}$	0.298	0.000	-0.298
$v_{gy}$	0.140	0.000	-0.140
$v_{gz}$	0.213	0.000	-0.213
XIMUX	-0.3003320	-0.3014345	<sup>a</sup> -0.0011025
XIMUY	-0.8063816	-0.8067625	-0.0003809
XIMUZ	-0.5094598	-0.5082042	0.0012556
YIMUX	0.0880600	0.0843727	-0.0036873
YIMUY	0.5083955	0.5083357	-0.0000598
YIMUZ	-0.8566093	-0.8570158	-0.0004065
ZIMUX	0.9497611	0.9497465	-0.0000146
ZIMUY	-0.3021303	-0.3012127	0.0009176
ZIMUZ	-0.0816775	-0.0851613	-0.0034838
a	157697.420	157697.0	-0.420
e	0.97738	0.97738	0.0
i	31.830	31.830	0.0
PTRIM	1.01	1.00	-0.01
YTRIM	-0.22	-0.2	0.02
IGA	247.04	247.10	<sup>a</sup> -0.06
MGA	357.5	357.40	<sup>a</sup> 0.10
OGA	358.75	358.60	<sup>a</sup> 0.15
PITCH	-81.00	-80.90	<sup>a</sup> 0.10
YAW	-6.78	-6.90	<sup>a</sup> -0.12
ROLL	4.77	4.90	<sup>a</sup> 0.13

<sup>a</sup> Refer to SPS discussion.

TABLE II.- CASE 2: LOI-1, MOON REFERENCE

Parameter	GPB value	RTCC value	RTYC - GPB difference
$\Delta t$ burn	334.60	334.76	<sup>a</sup> 0.16
$\Delta V_x$	-2767.90	-2767.90	0.00
$\Delta V_y$	45.2	45.2	0.00
$\Delta V_z$	-747.6	-747.6	0.00
$\Delta V_m$	2867.46	2867.5	0.04
$V_{gx}$	1.400	0.000	<sup>a</sup> -1.40
$V_{gy}$	0.754	0.000	-0.754
$V_{gz}$	0.523	0.000	-0.523
XIMUX	-0.9536994	-0.9540366	<sup>a</sup> -0.0003372
XIMUY	-0.2548466	-0.2542778	0.0005688
XIMUZ	-0.0597207	-0.1586097	0.0011110
YIMUX	0.0407015	0.0400325	-0.0006690
YIMUY	0.4168096	0.4163737	-0.0031359
YIMUZ	-0.9080821	-0.9083118	-0.0002297
ZIMUX	0.2979948	0.2970045	-0.0009903
ZIMUY	-0.8725382	-0.8729122	<sup>a</sup> 0.0003740
ZIMUZ	-0.3871384	-0.3870564	0.0000820
a	1052.987	1052.665	-0.322
e	0.0526	0.0522	-0.0004
i	154.11	154.12	0.0100
PTRIM	1.02	1.00	-0.02
YTRIM	-0.22	-0.2	0.02
IGA	302.50	302.70	<sup>a</sup> 0.20
MGA	353.17	353.10	<sup>a</sup> -0.07
OGA	6.28	6.30	<sup>a</sup> 0.02
PITCH	16.25	16.30	<sup>a</sup> 0.05
YAW	178.30	178.30	<sup>a</sup> 0.00
ROLL	-0.17	-0.20	<sup>a</sup> -0.03

<sup>a</sup> Refer to SPS discussion.

TABLE III.- CASE 3: LOI-2, MOON REFERENCE

Parameter	GPB value	RTCC value	RTCC - GPB difference
$\Delta t$ burn	13.33	13.43	0.10
$\Delta V_x$	-136.79	-136.80	-0.01
$\Delta V_y$	0.00	0.00	0.00
$\Delta V_z$	-1.77	-1.77	0.00
$\Delta V_m$	136.80	136.80	0.00
$V_{gx}$	1.42	0.00	<sup>a</sup> -1.42
$V_{gy}$	0.088	0.00	0.088
$V_{gz}$	-0.072	0.00	-0.072
XIMUX	-0.7981265	-0.7980102	<sup>a</sup> 0.0001163
XIMUY	-0.51771049	-0.5187815	-0.0010710
XIMUZ	-0.30817195	-0.3066682	0.0015037
YIMUX	0.0703724	0.0689837	-0.0013883
YIMUY	0.42789080	0.4268911	-0.0009997
YIMUZ	-0.9010866	-0.9016680	-0.0005814
ZIMUX	0.5983659	0.5986826	0.0003167
ZIMUY	-0.7408679	-0.7406954	0.0001725
ZIMUZ	-0.3050784	-0.3048760	0.0002024
a	998.655	998.046	-0.609
e	0.00038	0.00036	-0.00002
i	154.11	154.11	0.00
PTRIM	1.38	1.40	0.02
YTRIM	-0.69	-0.60	0.09
IGA	282.40	282.40	<sup>a</sup> 0.00
MGA	353.24	353.10	<sup>a</sup> -0.14
OGA	4.03	4.00	<sup>a</sup> -0.03
PITCH	1.50	1.50	<sup>a</sup> 0.00
YAW	179.7	179.60	<sup>a</sup> -0.10
ROLL	0.00	0.00	<sup>a</sup> 0.00

a Refer to SPS discussion.

TABLE IV.- CASE 4: TRANSLUNAR MIDCOURSE CORRECTION, EARTH REFERENCE

Parameter	GPB value	RTCC value	RTCC - GPB difference
$\Delta t_{burn}$	4.38	4.42	0.04
$\Delta V_x$	2.60	2.60	0.00
$\Delta V_y$	0.80	0.80	0.00
$\Delta V_z$	31.80	31.80	0.00
$\Delta V_m$	31.90	31.90	0.00
$V_{gx}$	0.120	0.00	-0.120
$V_{gy}$	0.103	0.00	-0.103
$V_{gz}$	0.140	0.00	-0.140
XIMUX	-0.0086641	-0.0105032	<sup>a</sup> 0.0001609
XIMUY	-0.8455825	-0.8453545	0.0002280
XIMUZ	-0.53377441	-0.5341025	0.0006719
YIMUX	0.41187478	0.4114238	-0.0004509
YIMUY	0.48438230	0.4831726	-0.0012097
YIMUZ	-0.77295860	-0.7728355	0.0001231
ZIMUX	0.91299670	0.9113837	-0.0016130
ZIMUY	-0.22441920	-0.2278597	-0.0034405
ZIMUZ	0.34269480	0.3427240	0.0000292
a	158330.305	158330.812	0.507
e	0.9774	0.9774	0.0
i	31.83	31.83	0.0
PTRIM	1.01	1.00	-0.01
YTRIM	-0.22	-0.20	0.02
IGA	230.20	230.30	<sup>a</sup> 0.10
MGA	359.50	359.50	<sup>a</sup> 0.00
OCA	17.08	17.30	<sup>a</sup> 0.22
PITCH	-83.92	-83.80	<sup>a</sup> 0.12
YAW	10.17	10.10	<sup>a</sup> 0.07
ROLL	6.90	7.20	<sup>a</sup> 0.30

<sup>a</sup> Refer to SPS discussion.

'TABLE V.- CASE 5: LOI-1, MOON REFERENCE

Parameter	GPB value	RTCC value	RTCC - GPB difference
$\Delta t$ burn	334.75	334.85	0.10
$\Delta V_x$	-2821.80	-2821.80	0.00
$\Delta V_y$	46.50	46.50	0.00
$\Delta V_z$	-549.00	-549.00	0.00
$\Delta V_m$	2875.10	2875.10	0.00
$V_{gx}$	1.43	0.00	<sup>a</sup> 1.43
$V_{gy}$	0.78	0.00	-0.78
$V_{gz}$	0.50	0.00	-0.50
XIMUX	-0.9401810	-0.9403731	<sup>a</sup> 0.0001921
XIMUY	-0.2919274	-0.2917370	0.0001904
XIMUZ	-0.1756076	-0.1748941	0.0007135
YIMUX	0.0402435	0.0397745	-0.0004690
YIMUY	0.4166898	0.4163356	-0.0003542
YIMUZ	-0.9081575	-0.9083406	-0.0001831
ZIMUX	0.3382899	0.3378112	-0.0004787
ZIMUY	-0.8608995	-0.8611354	-0.0002359
ZIMUZ	-0.3799156	-0.3799071	0.0000085
a	1049.727	1049.684	0.0001
e	0.0541	0.0542	0.0001
i	154.11	154.13	0.02
PTRIM	1.01	1.00	-0.01
YTRIM	-0.22	-0.20	-0.02
IGA	299.70	299.70	<sup>a</sup> 0.00
MGA	352.80	352.80	<sup>a</sup> 0.00
OGA	5.98	6.00	<sup>a</sup> 0.02
PITCH	12.15	12.20	<sup>a</sup> 0.05
YAW	178.30	178.30	<sup>a</sup> 0.00
ROLL	-0.16	-0.20	<sup>a</sup> 0.04

<sup>a</sup> Refer to SPS discussion.

TABLE VI.- CASE 6: PLANE CHANGE, MOON REFERENCE

Parameter	GPB value	RTCC value	RTCC - GPB difference
At burn	48.28	48.38	0.10
$\Delta V_x$	-83.30	-83.30	0.00
$\Delta V_y$	-952.80	-952.80	0.00
$\Delta V_z$	-1.80	-1.80	0.00
$\Delta V_m$	956.44	956.44	0.00
$V_{gx}$	2.67	0.00	<sup>a</sup> -2.67
$V_{gy}$	0.497	0.00	-0.497
$V_{gz}$	0.069	0.00	-0.069
XIMUX	-0.0381745	-0.0426107	<sup>a</sup> 0.0044367
XIMUY	0.4019294	0.4012109	-0.0007185
XIMUZ	-0.9148745	-0.9149941	-0.0001196
YIMUX	0.7454227	0.7460920	0.0006693
YIMUY	0.6211898	0.6218777	0.0006872
YIMUZ	0.2418017	0.2419388	0.0001371
ZIMUX	0.6654980	0.6644781	-0.0010199
ZIMUY	-0.6727376	-0.6725310	0.0002066
ZIMUZ	-0.3233210	-0.3258389	-0.0023179
a	1049.60	1049.67	0.01
e	0.054	0.054	0.00
i	160.650	160.665	-0.015
PTRIM	-0.67	-0.80	<sup>a</sup> 0.13
YTRIM	0.06	0.30	<sup>a</sup> 0.24
IGA	275.03	275.7	<sup>a</sup> 0.67
MGA	77.14	76.90	<sup>a</sup> 0.24
OGA	2.50	2.00	<sup>a</sup> 0.50
PITCH	2.98	3.10	<sup>a</sup> 0.12
YAW	-96.10	-96.20	<sup>a</sup> 0.10
ROLL	0.01	0.00	<sup>a</sup> 0.01

a Refer to SPS discussion.

TABLE VII.- CASE 7: PLANE CHANGE, EARTH REFERENCE

Parameter	GPB value	RTCC value	RTCC - GPB difference
$\Delta t$ burn	38.31	38.41	0.10
$\Delta V_x$	-3.90	-3.90	0.00
$\Delta V_y$	-446.50	-446.50	0.00
$\Delta V_z$	-0.10	-0.10	0.00
$\Delta V_m$	446.50	446.50	0.00
$V_{gx}$	1.48	0.00	<sup>a</sup> -1.48
$V_{gy}$	-0.02	0.00	0.02
$V_{gz}$	0.11	0.00	-0.11
XIMUX	-0.1833410	-0.1887510	<sup>a</sup> 0.0054100
XIMUY	-0.4638976	-0.4612679	0.0026297
XIMUZ	0.8667093	0.8669515	0.0002422
YIMUX	-0.2493401	-0.2472767	0.0020634
YIMUY	-0.8308784	-0.8320500	-0.0011716
YIMUZ	-0.4974641	-0.4965349	0.0009292
ZIMUX	0.9509025	0.9503827	-0.0005198
ZIMUY	-0.3073109	-0.3080984	-0.0007875
ZIMUZ	0.03666579	0.0329895	-0.0036762
a	3551.044	3551.037	0.007
e	31.58	31.58	0.00
i	0.0016	0.0016	0.00
PTRIM	-1.19	-1.50	<sup>a</sup> 0.31
YTRIM	1.29	1.30	<sup>a</sup> 0.01
IGA	11.12	9.60	<sup>a</sup> 1.52
MGA	276.00	276.10	<sup>a</sup> 0.10
OGA	127.00	126.00	<sup>a</sup> 1.00
PITCH	3.54	3.70	<sup>a</sup> 0.16
YAW	-92.74	-92.80	<sup>a</sup> 0.06
ROLL	-0.01	0.00	<sup>a</sup> 0.01

<sup>a</sup> Refer to SPS discussion.

TABLE VIII.- CASE 8: MINIMUM IMPULSE, EARTH REFERENCE

Parameter	GPB value	RTCC value	RTCC - GPB difference
$\Delta t$ burn	7.34	7.44	0.10
$\Delta V_x$	89.10	89.10	0.00
$\Delta V_y$	0.00	0.00	0.00
$\Delta V_z$	0.40	0.40	0.00
$\Delta V_m$	89.10	89.10	0.00
$V_{gx}$	1.50	0.00	-1.50
$V_{gy}$	-0.65	0.00	0.65
$V_{gz}$	-0.575	0.00	0.575
XIMUX	0.9523636	0.9536159	<sup>a</sup> 0.0012523
XIMUY	0.1307557	0.1243434	-0.0064123
XIMUZ	0.2755112	0.2741448	-0.0013664
YIMUX	0.1735866	0.1748504	0.0012638
YIMUY	0.5103657	0.5125224	0.0021567
YIMUZ	-0.8422556	-0.8406831	0.0015725
ZIMUX	-0.2507412	-0.2450388	0.0057024
ZIMUY	0.8499586	0.8496232	-0.0003354
ZIMUZ	0.4633563	0.4670080	0.0036517
<i>a</i>	3573.672	3573.795	0.123
<i>e</i>	0.00780	0.00795	0.00015
<i>i</i>	31.54	31.54	0.00
PTRIM	-1.04	-1.40	<sup>a</sup> 0.36
YTRIM	1.25	1.40	<sup>a</sup> 0.15
IGA	124.3	125.1	<sup>a</sup> 0.80
MGA	358.04	357.40	<sup>a</sup> 0.64
OGA	359.16	359.9	<sup>a</sup> 0.74
PITCH	3.08	3.03	<sup>a</sup> -0.05
YAW	-2.22	-2.30	<sup>a</sup> -0.08
ROLL	0.00	0.00	<sup>a</sup> 0.00

<sup>a</sup> Refer to SPS discussion.

TABLE IX.- CASE 9: TRANSLUNAR MIDCOURSE CORRECTION, EARTH REFERENCE

Parameter	GPB value	RTCC value	RTCC - GPB difference
$\Delta t_{burn}$	1.477	1.48	0.003
$\Delta V_x$	10.00	10.00	0.00
$\Delta V_y$	15.00	15.00	0.00
$\Delta V_z$	-5.00	-5.00	0.00
$\Delta V_m$	18.70	18.70	0.00
$V_{gx}$	0.85	0.00	-0.85
$V_{gy}$	-0.10	0.00	0.10
$V_{gz}$	-0.09	0.00	0.09
XIMUX	-0.1098437	-0.1065661	<sup>a</sup> 0.0032776
XIMUY	0.9220384	0.9246371	0.0025787
XIMUZ	-0.3711353	-0.3656364	0.0054989
YIMUX	0.7002138	0.6984261	-0.0017877
YIMUY	-0.1932199	-0.1921247	0.0010952
YIMUZ	-0.6982893	-0.6894122	-0.0021229
ZIMUX	-0.7054317	-0.7077038	-0.0022721
ZIMUY	-0.3353717	-0.3288379	0.0065338
ZIMUZ	-0.6244132	-0.6253166	-0.0009034
a	3576.20	3576.36	0.16
e	0.0065	0.0065	0.00
i	31.53	31.53	0.00
PTRIM	-1.01	-1.4	<sup>a</sup> 0.39
YTRIM	1.25	1.4	<sup>a</sup> 0.15
IGA	29.85	30.3	<sup>a</sup> 0.40
MGA	52.30	52.0	<sup>a</sup> 0.30
OGA	335.4	335.1	<sup>a</sup> 0.30
PITCH	3.28	3.30	<sup>a</sup> 0.02
YAW	-2.22	-2.30	<sup>a</sup> 0.08
ROLL	0.00	0.00	<sup>a</sup> 0.00

<sup>a</sup> Refer to SPS discussion.

'TABLE X.- ANGULAR DIFFERENCE BETWEEN XIMU's<sup>a</sup>

Case no.	Angle between XIMU's, deg	Angular difference caused by c.g. location, A, deg	Angular difference between the desired thrust direction, B, deg	A + B
1	0.10016	0.07082	0.02876	0.09958
2	0.07164	0.07082	0.0000	0.07082
3	0.10720	0.10249	0.02017	0.12266
4	0.10813	0.07082	0.04438	0.11520
5	0.07593	0.06767	0.00000	0.06767
6	0.25791	0.26977	0.00000	0.26977
7	0.34571	0.31164	0.00887	0.32052
8	0.38313	0.35869	0.00768	0.36638
9	0.40029321	0.38802786	0.00256200	0.39058986

<sup>a</sup>For table explanation, refer to SPS discussion.

TABLE XI.- CASE 10: DPS MINIMUM IMPULSE, MOON REFERENCE

Parameter	GPB value	RTCC value	RTCC - GPB difference
$\Delta t$ burn	4.71	4.76	0.05
$\Delta V_x$	-6.60	-6.60	0.00
$\Delta V_y$	0.00	0.00	0.00
$\Delta V_z$	0.00	0.00	0.00
$\Delta V_m$	6.60	6.60	0.00
$V_{gx}$	1.90	0.00	<sup>a</sup> -1.90
$V_{gy}$	-0.15	0.00	<sup>a</sup> 0.15
$V_{gz}$	0.10	0.00	<sup>a</sup> 0.10
XIMUX	0.3636955	0.3628817	<sup>a</sup> -0.0008138
XIMUY	0.9115338	0.9120601	0.0005263
XIMUZ	-0.1919156	-0.1909533	0.0009623
YIMUX	-0.7171045	-0.7171049	-0.0000004
YIMUY	0.1424783	0.1424763	-0.0000020
YIMUZ	-0.6822470	-0.6822471	-0.0000001
ZIMUX	-0.5945474	-0.5950440	-0.0004966
ZIMUY	0.3857537	0.3845086	-0.0012451
ZIMUZ	0.7054838	0.7057448	0.0000261
a	1016.32	1016.24	-0.08
e	0.00233	0.00246	0.00013
i	133.01	133.01	0.00
PTRIM	5.40	5.60	<sup>a</sup> 0.20
YTRIM	7.49	7.30	<sup>a</sup> -0.19
IGA	27.82	27.80	<sup>a</sup> -0.02
OGA	290.28	290.30	<sup>a</sup> 0.02
MGA	65.72	65.80	<sup>a</sup> 0.08

<sup>a</sup> Refer to DPS and APS discussion.

TABLE XIII.- CASE 11: DPS HEIGHT ADJUSTMENT, MOON REFERENCE

Parameter	GPB value	RTCC value	RTCC - GPB difference
$\Delta t$ burn	37.90	37.80	-0.10
$\Delta V_x$	122.98	123.00	0.02
$\Delta V_y$	0.00	0.00	0.00
$\Delta V_z$	2.86	2.80	0.02
$\Delta V_m$	123.02	123.10	0.08
$V_{gx}$	-3.58	0.00	<sup>a</sup> 3.58
$V_{gy}$	-0.03	0.00	0.03
$V_{gz}$	-0.15	0.00	0.15
XIMUX	-0.2277739	-0.2276791	<sup>a</sup> 0.0000948
XIMUY	-0.9729605	-0.9729865	-0.0000260
XIMUZ	0.0382985	0.0382035	-0.0000950
YIMUX	0.7171250	0.7171262	0.0000012
YIMUY	-0.1410154	-0.1410088	0.0000066
YIMUZ	0.6825293	0.6825295	-0.0000002
ZIMUX	-0.6586734	-0.6587050	-0.0000316
ZIMUY	0.1829272	0.1827945	-0.0001327
ZIMUZ	0.7298540	0.7298589	0.0000048
a	1066.01	1066.13	0.12
e	0.04331	0.04447	0.00116
i	133.04	133.04	0.00
PTRIM	5.44	5.60	<sup>a</sup> 0.16
YTRIM	7.22	7.30	<sup>a</sup> 0.08
IGA	-0.28	0.00	<sup>a</sup> 0.28
OGA	0.06	0.00	<sup>a</sup> -0.06
MGA	1.09	0.00	<sup>a</sup> -1.09

<sup>a</sup> Refer to DPS and APS discussion.

TABLE XIII.- CASE 12: APS MINIMUM IMPULSE, MOON REFERENCE

Parameter	GPB value	RTCC value	RTCC - GPB difference
$\Delta t_{burn}$	0.48	0.44	-0.04
$\Delta V_x$	-6.50	-6.50	0.00
$\Delta V_y$	0.00	0.00	0.00
$\Delta V_z$	0.00	0.00	0.00
$\Delta V_m$	6.50	6.50	0.00
$V_{gx}$	1.58	0.00	<sup>a</sup> -1.58
$V_{gy}$	-0.07	0.00	0.07
$V_{gz}$	-0.07	0.00	0.07
XIMUX	0.2822217	0.2820594	<sup>a</sup> -0.0001623
XIMUY	0.9542953	0.9543619	0.0000766
XIMUZ	-0.0983434	-0.0981624	0.0001810
YIMUX	-0.7171123	-0.7171127	0.0000004
YIMUY	0.1417550	0.1417526	0.0000024
YIMUZ	-0.6823894	-0.6823896	0.0000002
ZIMUX	-0.6372600	-0.6373319	-0.0000719
ZIMUY	0.2631083	0.2628679	-0.0002404
ZIMUZ	0.7243432	0.7243677	0.0000245
a	1016.31	1016.22	-0.09
e	0.0024	0.0025	0.0001
i	133.03	133.03	0.00
PTRIM	-1.50	-1.50	0.00
YTRIM	0.00	0.00	0.00
IGA	-1.33	0.00	<sup>a</sup> 1.33
OGA	-0.18	0.00	<sup>a</sup> 0.18
MGA	-0.01	0.00	<sup>a</sup> 0.01

Refer to DPS and APS discussion.

TABLE XIV.- CASE 13: APS PLANE CHANGE, MOON REFERENCE

Parameter	GPB value	RTCC value	RTCC - GPB difference
$\Delta t$ burn	39.17	39.81	<sup>a</sup> 0.64
$\Delta V_x$	-20.10	-20.10	0.00
$\Delta V_y$	-461.00	-461.00	0.00
$\Delta V_z$	-0.35	-0.30	0.05
$\Delta V_m$	461.43	461.40	-0.03
$V_{gx}$	-0.07	0.00	0.07
$V_{gy}$	-0.29	0.00	0.29
$V_{gz}$	-0.32	0.00	0.32
XIMUX	-0.6870770	-0.6870410	<sup>a</sup> 0.0000360
XIMUY	0.1572742	0.1573017	-0.0000375
XIMUZ	-0.7093588	-0.7093877	0.0000289
YIMUX	-0.7033844	-0.7034193	0.0000349
YIMUY	-0.3887121	-0.3887124	0.0000003
YIMUZ	0.5951076	0.5950664	-0.0000412
ZIMUX	-0.1821413	-0.1821428	-0.0000015
ZIMUY	0.9078368	0.9078319	-0.0000049
ZIMUZ	0.3776994	0.3777104	0.0000110
a	1016.39	1016.42	0.03
e	0.00259	0.00249	-0.00010
i	137.30	137.30	0.00
PTRIM	-1.50	-1.50	0.00
YTRIM	0.00	0.00	0.00
IGA	-1.33	0.00	<sup>a</sup> 1.33
OGA	-0.02	0.00	<sup>a</sup> 0.02
MGA	-0.05	0.00	<sup>a</sup> 0.05

<sup>a</sup>Refer to DPS and APS discussion.

TABLE XV.-- CASE 14: APS APOLUNE CHANGE, MOON REFERENCE

Parameter	GPB value	RTCC value	RTCC - GPB difference
$\Delta t$ burn	7.14	7.28	<sup>a</sup> 0.14
$\Delta V_x$	87.20	87.20	0.00
$\Delta V_y$	0.00	0.00	0.00
$\Delta V_z$	0.28	0.30	0.02
$\Delta V_m$	87.20	87.20	0.00
$V_{gx}$	-0.12	0.00	0.12
$V_{gy}$	-0.49	0.00	0.49
$V_{gz}$	-0.85	0.00	0.85
XIMUX	0.2194719	0.2194551	<sup>a</sup> -0.0000168
XIMUY	0.9750606	0.9750610	0.0000034
XIMUZ	0.3299848	0.0330109	0.0000261
YIMUX	0.6555214	0.6555216	0.0000002
YIMUY	-0.1724302	-0.1724278	0.0000022
YIMUZ	0.7352275	0.7352279	0.0000004
ZIMUX	0.7225813	0.7225862	0.0000049
ZIMUY	-0.1397305	-0.1397102	0.0000203
ZIMUZ	-0.6770166	-0.6770157	0.0000009
$a$	1051.21	1051.20	-0.01
$e$	0.0349	0.0359	0.0010
$i$	137.32	137.32	0.00
PTRIM	-1.50	-1.50	0.00
YTRIM	0.00	0.00	0.00
IGA	-1.10	0.00	<sup>a</sup> -1.10
OGA	-0.014	0.000	<sup>a</sup> 0.014
MGA	0.14	0.00	<sup>a</sup> 0.14

<sup>a</sup> Refer to DPS and APS discussion.

TABLE XVI.- CASE 15: APS APOGEE CHANGE, EARTH REFERENCE

Parameter	GPB value	RTCC value	RTCC - GPB difference
$\Delta t_{burn}$	15.28	15.48	<sup>a</sup> 0.20
$\Delta V_x$	177.00	177.00	0.00
$\Delta V_y$	0.00	0.00	0.00
$\Delta V_z$	1.65	1.60	-0.05
$\Delta V_m$	177.00	177.00	0.00
$V_{gx}$	-0.24	0.00	0.24
$V_{gy}$	-0.61	0.00	0.61
$V_{gz}$	-0.60	0.00	0.60
XIMUX	0.9848907	0.9848865	<sup>a</sup> 0.0000042
XIMUY	-0.1661146	-0.1664405	-0.0000259
XIMUZ	0.0479032	0.0479176	0.0000149
YIMUX	0.1287446	0.1287561	0.0000115
YIMUY	0.5185360	0.5185342	-0.0000018
YIMUZ	-0.8453077	-0.8453071	0.0000006
ZIMUX	0.1158231	0.1158464	0.0000233
ZIMUY	0.8387053	0.8387013	-0.0000040
ZIMUZ	0.5321263	0.5321276	-0.0000013
a	3593.32	3593.22	-0.10
e	0.0149	0.0149	0.00
i	32.295	32.295	0.00
PTRIM	-1.50	-1.50	0.00
YTRIM	0.00	0.00	0.00
IGA	-1.23	0.00	<sup>a</sup> 1.23
OGA	-0.02	0.00	<sup>a</sup> 0.02
MGA	-0.05	0.00	<sup>a</sup> 0.05

<sup>a</sup> Refer to DPS and APS discussion.

TABLE XVII.- CASE 16: DPS PLANE CHANGE, EARTH REFERENCE

Parameter	GPB value	RTCC value	RTCC - GPB difference
$\Delta t$ burn	108.03	107.97	0.06
$\Delta V_x$	-15.55	-15.50	0.05
$\Delta V_y$	-893.10	-893.10	0.00
$\Delta V_z$	-1.25	-1.20	0.05
$\Delta V_m$	893.20	893.10	0.10
$V_{gx}$	-2.99	0.00	<sup>a</sup> 2.99
$V_{gy}$	-0.21	0.00	0.21
$V_{gz}$	0.08	0.00	-0.08
XIMUX	-0.1241948	-0.1241762	<sup>a</sup> 0.0000186
XIMUY	-0.5049605	-0.5049865	-0.0000260
XIMUZ	0.8541607	0.8541480	-0.0000127
YIMUX	-0.2797436	-0.2797453	-0.0000017
YIMUY	-0.8080883	-0.8080756	0.0000137
YIMUZ	-0.5183982	-0.5184172	-0.0000190
ZIMUX	0.9520079	0.9520099	0.0000020
ZIMUY	-0.3033284	-0.3033189	0.0000095
ZIMUZ	-0.0408990	-0.0409239	-0.0000249
a	3546.71	3546.68	0.03
e	0.00139	0.00139	0.00
i	30.335	30.335	0.00
PTRIM	5.45	5.60	<sup>a</sup> 0.15
YTRIM	7.24	7.30	<sup>a</sup> 0.06
IGA	-0.28	0.00	<sup>a</sup> 0.28
OGA	0.06	0.00	<sup>a</sup> -0.06
MGA	1.09	0.00	<sup>a</sup> -1.09

<sup>a</sup>Refer to DPS and APS discussion.

TABLE XVIII.- CASE 17: LM RCS EXTERNAL  $\Delta V$  BURN

Parameter	GPB value	RTCC value	RTCC - GPB difference
$\Delta t$ burn (6D)	112.47	109.16	<sup>a</sup> -3.31
$\Delta t$ burn (3D)	109.06	109.16	0.10
$\Delta V_x$	116.46	116.50	0.04
$\Delta V_y$	-30.00	-30.00	0.00
$\Delta V_z$	75.73	75.70	-0.03
$\Delta V_m$	142.10	142.10	0.00
$V_{gx}$	0.00	0.00	0.00
$V_{gy}$	0.00	0.00	0.00
$V_{gz}$	0.00	0.00	0.00
XIMUX	0.8478221	0.8478205	<sup>a</sup> -0.0000016
XIMUY	0.5211817	0.5211845	0.0000028
XIMUZ	0.0978125	0.0978119	-0.0000006
YIMUX	0.0300865	0.0300864	-0.0000001
YIMUY	0.9723851	0.9723858	0.0000007
YIMUZ	0.8623851	0.9723858	0.0000007
ZIMUX	0.5294265	0.5294292	0.0000027
ZIMUY	-0.8214667	-0.8214658	-0.0000009
ZIMUZ	-0.2118959	-0.2118933	-0.0000026
PTRIM	0.00	0.00	0.00
YTRIM	0.00	0.00	0.00
IGA	0.00	0.00	0.00
OGA	0.00	0.00	0.00
MGA	0.00	0.00	0.00

<sup>a</sup> Refer to DPS and APS discussion.

TABLE XIX.- CASE 18: LONG APS BURN 6D

Parameter	GPB value	RTCC value	RTCC - GPB difference
$\Delta t$ burn	156.64	162.56	<sup>a</sup> 5.92
$\Delta V_x$	53.00	53.00	0.00
$\Delta V_y$	3000.00	3000.00	0.00
$\Delta V_z$	-396.97	-397.00	0.03
$\Delta V_m$	3026.60	3026.60	0.00
$V_{gx}$	0.46	0.00	<sup>a</sup> -0.46
$V_{gy}$	15.00	0.00	<sup>a</sup> -15.00
$V_{gz}$	3.30	0.00	<sup>a</sup> -3.30
XIMUX	-0.1892509	-0.1892505	<sup>a</sup> -0.0000004
XIMUY	-0.3707642	-0.3707627	-0.0000015
XIMUZ	0.9092403	0.9092410	0.0000007
YIMUX	-0.4304187	-0.4304150	-0.0000037
YIMUY	-0.8009504	-0.8009533	-0.0000029
YIMUZ	-0.4161947	-0.4161931	-0.0000016
ZIMUX	0.8825665	0.8825685	0.0000020
ZIMUY	-0.4701193	-0.4701158	0.0000035
ZIMUZ	-0.0080032	-0.0080010	0.0000022
PTRIM	-1.50	-1.50	0.00
YTRIM	0.00	0.00	0.00
IGA	-1.65	0.00	<sup>a</sup> 1.65
OGA	0.06	0.00	<sup>a</sup> -0.06
MGA	-0.01	0.00	<sup>a</sup> 0.01

<sup>a</sup> Refer to DPS and APS discussion.

TABLE XX.- CASE 18a: LONG APS BURN 3D

Parameter	GPB value	RTCC value	RTCC - GPB difference
$\Delta t$ burn	162.64	162.56	0.08
$\Delta V_x$	53.00	53.00	0.00
$\Delta V_y$	3000.00	3000.00	0.00
$\Delta V_z$	-396.97	-397.00	0.03
$\Delta V_m$	3026.60	3026.60	0.00
$V_{gx}$	-0.38	0.00	0.38
$V_{gy}$	-0.76	0.00	0.76
$V_{gz}$	0.86	0.00	-0.86
XIMUX	-0.1892509	-0.1892505	<sup>a</sup> -0.0000004
XIMUY	-0.3707642	-0.3707627	-0.0000015
XIMUZ	0.9092403	0.9092410	0.0000007
YIMUX	-0.4304187	-0.4304150	-0.0000037
YIMUY	-0.8009504	-0.8009533	-0.0000029
YIMUZ	-0.4161947	-0.4161931	0.0000016
ZIMUX	0.8825665	0.8825685	0.0000020
ZIMUY	-0.4701193	-0.4701158	0.0000035
ZIMUZ	-0.0080032	-0.0080010	0.0000022
PTRIM	-1.50	-1.50	0.00
YTRIM	0.00	0.00	0.00
IGA	0.00	0.00	0.00
OGA	0.00	0.00	0.00
MGA	0.00	0.00	0.00

<sup>a</sup> Refer to DPS and APS discussion.

TABLE XXI.- COMPARISON FOR COMPUTED LM REFSMMAT

Case A	GPB	RTCC	RTCC - GPB difference
XIMUX	-0.5229827	-0.5229827	0.0E-6
XIMUY	-0.2478033	-0.2478033	0.0E-6
XIMUZ	0.8155259	0.8155260	0.1E-6
YIMUX	-0.5370326	-0.5370326	0.0E-6
YIMUY	0.8387985	0.8387986	0.1E-6
YIMUZ	-0.0895149	-0.0895149	0.0E-6
ZIMUX	-0.6618799	-0.6618799	0.0E-6
ZIMUY	-0.4847799	-0.4847788	0.0E-6
ZIMUZ	-0.5717556	-0.5717556	0.0E-6
Case B			
XIMUX	0.3107043	0.3107043	0.0E-6
XIMUY	0.2528569	0.2528569	0.0E-6
XIMUZ	-0.9162574	-0.9162566	0.8E-6
YIMUX	-0.7380460	-0.7380461	0.0E-6
YIMUY	-0.5432604	-0.5432604	0.0E-6
YIMUZ	-0.4001946	-0.4001950	0.4E-6
ZIMUX	-0.5987580	-0.5989581	0.1E-6
ZIMUY	0.8005819	0.8005819	0.0E-6
ZIMUZ	0.0178267	0.0178267	0.0E-6
Case C			
XIMUX	-0.4107330	-0.4107331	0.0E-6
XIMUY	-0.1376257	-0.1376257	0.0E-6
XIMUZ	-0.9013088	-0.9013088	0.0E-6
YIMUX	-0.1688434	-0.1688435	0.1E-6
YIMUY	-0.9599626	-0.9599627	0.1E-6
YIMUZ	0.2235251	0.2235251	0.0E-6
ZIMUX	-0.8959856	-0.8959856	0.0E-6
ZIMUY	0.2439892	0.2439893	0.1E-6
ZIMUZ	0.3710512	0.3710513	0.1E-6

TABLE XIII.- CASE 19: DPS EXTERNAL  $\Delta V$  BURN 6D AND 3D

Parameter	PICICS (RTCC)	AGS (ARM-6D)	RTCC - GPB difference	AGS (ARM-3D)	RTCC - GPB difference
$\Delta t$ burn	15.48	15.59	0.11	15.45	0.03
$\Delta V_x$	177.0	177.0	NA	177.00	NA
$\Delta V_y$	0.0	0.0	NA	0.0	NA
$\Delta V_z$	1.6	2.4	NA	2.40	NA
$\Delta V_m$	177.0	177.0	0.0	177.0	0.0
a	3593.22	3593.22	0.00	3593.22	0.00
e	0.0149	0.0149	0.00	0.0149	0.00
i	32.29	32.29	0.00	32.29	0.00
$\Omega$	346.05	346.06	0.01	346.05	0.00
$\omega$	275.00	274.54	0.46	275.00	0.00
f	0.6663	1.1128	0.4465	1.0300	0.3667

TABLE XXXII.- CASE 20: APS EXTERNAL ΔV BURN, 6D AND 3D

Parameter	PGNCS (RTCC)	AGS (ARM-6D)	RTCC - GPB difference	AGS (ARM-3D)	RTCC - GPB difference
Δt burn	37.80	37.23	0.47	37.78	0.02
ΔV <sub>x</sub>	123.00	123.00	NA	123.00	NA
ΔV <sub>y</sub>	0.00	0.00	NA	0.00	NA
ΔV <sub>z</sub>	2.80	4.40	NA	4.40	NA
ΔV <sub>m</sub>	123.10	123.07	0.03	123.07	0.03
a	1066.13	1066.33	0.20	1066.11	0.02
e	0.044	0.044	0.00	0.044	0.00
i	133.04	133.04	0.00	133.04	0.00
Ω	258.87	258.86	-0.01	258.86	0.01
ω	272.56	272.46	-0.10	272.53	0.03
f	0.897	0.969	0.072	0.886	0.011

TABLE XXIV.- CASE 21: APS EXTERNAL  $\Delta V$  BURN, 6D AND 3D

Parameter	PGMCS (RTCC)	AGS (ARM-6D)	RTCC - GPB difference	AGS (ARM-3D)	RTCC - GPB difference
$\Delta t_{burn}$	7.28	7.36	0.08	7.26	0.02
$\Delta V_x$	87.20	87.10	NA	NA	NA
$\Delta V_y$	0.00	3.80	NA	NA	NA
$\Delta V_z$	0.30	0.50	NA	NA	NA
$\Delta V_m$	87.2	87.2	0.00	87.2	0.00
$a$	1051.20	1051.25	0.05	1051.21	0.01
$e$	0.0359	0.0359	0.00	0.0359	0.00
$i$	137.32	137.32	0.00	137.32	0.00
$\Omega$	255.26	255.28	0.02	255.26	0.00
$w$	87.27	87.24	0.03	87.26	0.01
$f$	0.1291	0.1485	0.0194	0.1342	0.0031

## REFERENCES

1. Hinson, S.: F mission (505/106/LM-4) RTCC Real Time Program System Parameters. MSC memo, March 28, 1969.
2. Revision I to the CSM/LM Spacecraft Operational Data Book, Volume III - Mass Properties. SNA-8-D-027, November 1968.
3. Revision I to the CSM/LM Spacecraft Operational Data Book, Volume I - CSM Data Book. SNA-8-D-027, November 1968.
4. CSM/LM Spacecraft Operational Data Book, Volume II - LM Data Book. SNA-8-D-027, June 1968.
5. Miles, Harry J.: Verification of RTCC Powered Flight Simulation for the Apollo 10 Mission. MSC memo, March 25, 1969.